

## 2.2 Inheritance



- ▶ **acquired traits:** traits acquired during a person's lifetime because of experiences, education, and upbringing, such as a scar from a cut or the ability to speak a particular language
- ▶ **inherited traits:** traits genetically passed on from one generation to the next, such as a particular blood type or eye colour

You have probably been told that you have characteristics similar to another member of your family. Perhaps someone has said that you have your mother's hair, your father's eyes, or that you inherited a trait from one of your grandparents. You might have compared your own characteristics to other family members or wondered which traits you might someday pass on to your children.

Although people have long understood that characteristics are inherited from their parents, they did not understand the mechanisms that enable inheritance to happen. As Mendel's work became more well known and understood, scientists were able to use his observations, terminology, and the results of his experiments to make predictions about how and what characteristics are passed on to offspring.

The discovery of genes and the field of genetic research has helped to answer questions concerning the inheritance of traits and the influence that one's surroundings has on the development of individuals. As more is learned about the role of genes and how they are passed on to offspring, scientists are better able to distinguish between **acquired traits**, which come from the environment and are not passed on to offspring, and **inherited traits**, which are the result of genes.

In Lesson 2.2 you will apply Mendel's work to making predictions about the genetic inheritance of single traits. Using genetic diagrams, you will analyze the probability of offspring inheriting particular traits. Through the study of autosomal and sex-linked patterns of inheritance, you will also learn why some diseases and characteristics are present in a particular gender more than they are in the other gender.

It is important to keep in mind that the study of human genetics is much more complicated than the introductory concepts taught in Science 30. The proper analysis of human genetic traits requires years of study and training. It follows that you must be cautious when it comes to drawing conclusions from an analysis of genetic traits based solely upon the information presented in this course.

**Figure A2.10:** Parents who are concerned about passing on a genetic disorder often seek the expertise of a genetics counsellor. A genetics counsellor studies for many years at a university to obtain a master's degree or PhD in medical genetics because it takes considerable expertise to properly interpret human genetic data.



## Practice

11. List five traits you may have inherited from your parents.
12. State some acquired traits that cannot be passed on to offspring.
13. Look at the family in the photograph.

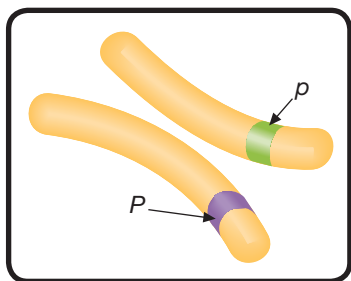


The mother and father have different eye colours, hair colours, hair types, and skin colours. Their little girls inherited some characteristics from each parent. Identify which characteristics the girls may have inherited from each parent.

## Alleles

At the beginning of Chapter 2 you looked at the ability to roll your tongue. You observed that there are two distinctive traits—some people can roll their tongues and others cannot. The differences in these traits can be traced to alternate forms of a specific gene. These alternate forms of genes are called **alleles**. In the case of tongue rolling, there are two alleles that can produce the two possible traits. One particular allele provides the genetic instructions that create the tongue-rolling trait; so if you do not possess that allele, you will not have the trait.

Individuals possess two alleles for every trait located at specific sites on homologous chromosomes. Since homologues separate during meiosis, only one of these alleles is passed onto each gamete. The two alleles that you inherit are contained in the particular sperm cell and egg cell that joined during fertilization. Therefore, when you think about inheritance, you also have to think about probability. In other words, which one allele of the two possibilities will be in each of the particular gametes that join to form an individual?

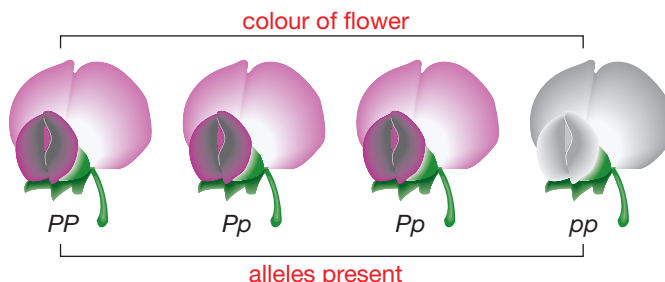


**Figure A2.11:** Two different alleles are found on a pair of homologous chromosomes.

## Dominant Versus Recessive

Gregor Mendel's studies of pea-plant traits that appear in two distinct forms can also be used to help understand how many traits, like tongue rolling, are expressed and passed on. In Mendel's experiments with pea-flower colour, he found that crossing a white-flowered plant with a purple-flowered plant resulted in all offspring producing purple flowers. This means that if an offspring receives a gene in the form of the purple allele from a parent, the purple colour will be produced even if the allele received from the other parent is the white gene. How can this be explained?

In genetic crosses between two individuals, each gene being studied is assigned a letter. Genes can be assigned any form of symbol, but using letters creates a way to easily represent the related, yet different, alleles.



**Figure A2.12:** Pea plants with purple flowers have at least one copy of the dominant allele, *P*. Pea plants with white flowers have two copies of the recessive allele, *p*.

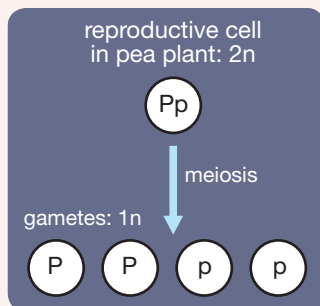
Mendel proposed a theory to describe the occurrence of traits that he observed in his pea-plant studies. Since the purple flower colour trait is dominant to the white trait, Mendel stated that the purple flower colour is a **dominant** trait in pea plants. Dominant traits are caused by dominant alleles. If an offspring receives even one dominant allele, the dominant trait will appear in that offspring. He said that the trait that is masked and not expressed when the dominant allele is present is called the **recessive** trait. Recessive traits are only expressed when an offspring receives two copies of the recessive allele. A white-flowered pea plant has two recessive alleles for flower colour.

The ability to roll your tongue is a dominant trait produced by the dominant allele, which you inherited from at least one of your parents. If you cannot roll your tongue, it means that you have two copies of the recessive allele.

- ▶ **allele:** an alternative form of a gene responsible for a trait
- ▶ **dominant:** referring to a dominant allele that overpowers a recessive allele—an individual only needs one dominant allele for the dominant trait to be expressed
- ▶ **recessive:** referring to a recessive allele that is not expressed when the dominant allele is present—two recessive alleles need to be present for the recessive trait to be expressed in an individual

## Example Problem 2.1

At a specific location on a particular chromosome within a pea plant is the gene that determines the flower colour. Since the pea plant has two copies of each chromosome, there are two copies of the gene for flower colour. However, the gene for flower colour located on each chromosome copy may not be identical. For example, one allele,  $P$ , codes for purple flowers, while the other allele,  $p$ , codes for white flowers. A reproductive cell within a pea plant can produce four gametes so that two of the gametes have the allele  $P$ , while the other two have the allele  $p$ .



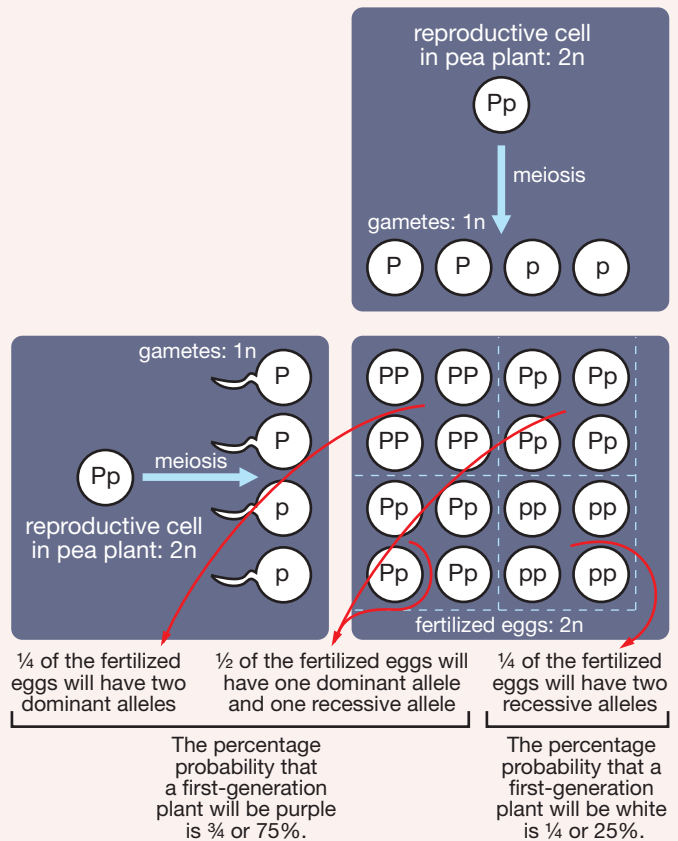
Suppose two pea plants each have the allele  $P$  that codes for purple flowers and the allele  $p$  that codes for white flowers. Let these two plants be the parent generation.

- Determine the colour of the flowers in each of the parent pea plants.
- Set up a chart to show all the possible outcomes of fertilizing a gamete from one plant with a gamete from the other.
- Use the chart you developed in b. to determine the percentage probability that a plant in the first generation of offspring will have white flowers.
- Suppose the two parent plants produced twelve plants in the first generation of offspring. How many of these plants would you expect to have white flowers? Suggest some reasons why the number of plants with white flowers could add up to a different number.

## Solution

- Each of the parent pea plants will produce purple flowers, since the dominant allele,  $P$ , for purple flowers masks the recessive allele,  $p$ , for white flowers.

b.



- The two parent plants each produce four gametes, combining for a total of sixteen possible offspring. Of these offspring, four have the two recessive alleles to produce white flowers. Since four of the sixteen possible outcomes produce white flowers, the percentage probability that a plant in the first generation will have white flowers is 1/4 or 25%.
- Since the percentage probability of an offspring in the first generation having white flowers is 1/4, then it is most likely that three plants (1/4 of the twelve offspring) will have white flowers. This value assumes that all the gametes are produced and fertilized in the exact proportions predicted by the chart. In reality, some of the sperm may not fertilize an egg and some eggs may not be fertilized by any sperm.



## Punnett Squares

As shown in Example Problem 2.1, if the alleles for an inherited trait are known, it is possible to predict the probability of the offspring having a particular genetic make-up or **genotype**.

But the method shown is lengthy and quite repetitious. Note that even though four gametes were produced by each parent plant, there were really only two possibilities: a gamete will either have the dominant allele or the recessive allele.

A streamlined version of this process uses a more concise chart called a **Punnett square**.

As you'll see in Example Problem 2.2, the Punnett square method is very efficient.

### How to Use a Punnett Square

**step 1:** Draw a square and then label each row and column with the alleles of each gamete.

**step 2:** Fill in the square with the offspring genotype.

**step 3:** Determine the fraction of the offspring with each genotype. This fraction is the same as the probability of an individual offspring possessing a particular genotype.

► **genotype:** a description of the alleles that an individual possesses

This is communicated by using letters to represent the different allele versions.

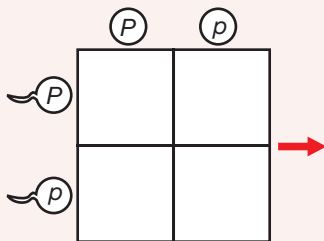
► **Punnett square:** a table that uses the alleles of the parents to indicate all possible outcomes resulting from gamete fertilization

### Example Problem 2.2

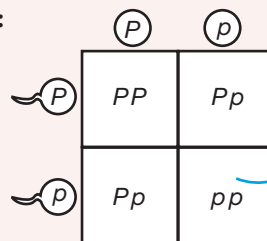
Two pea plants in the parent generation each contain the dominant allele  $P$  that codes for purple flowers and the recessive allele  $p$  that codes for white flowers. Use a Punnett square to predict the percentage probability that a plant in the first generation of offspring will have white flowers.

#### Solution

step 1:



step 2:



The percentage probability of plants in the first generation having white flowers is 25%.

### Practice

Use the following information to answer questions 14 and 15.

In human beings, the ability to roll one's tongue is dominant over non-tongue rolling. As you solve the following questions, use  $R$  to represent the dominant allele for tongue rolling and  $r$  to represent the recessive allele for non-tongue rolling.

14. Two parents each possess the dominant allele  $R$  and the recessive allele  $r$ .

Use a Punnett square to determine the percentage probability that their offspring will be able to roll their tongues.

15. One parent possesses the dominant allele  $R$  and the recessive allele  $r$ . The other parent possesses two copies of the recessive allele  $r$ .

- Are both of these parents able to roll their tongues?
- Use a Punnett square to determine the percentage probability that their offspring will be able to roll their tongues.



## Homozygous and Heterozygous

Punnett squares are a powerful tool to show the outcomes of several types of crosses.

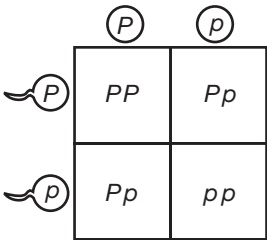
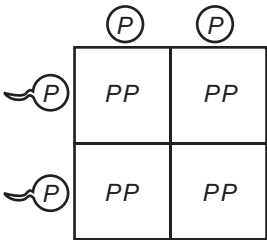
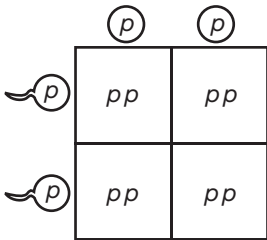
When an organism has two copies of the same alleles that are either both dominant or both recessive, the organism is called **homozygous**. In the case of pea plants, the purple flowers are homozygous for the dominant condition and the white flowers are homozygous for the recessive condition. When an organism possesses one dominant allele and one recessive allele for a trait, it is said to be **heterozygous** for that trait.

The following table shows some of these possibilities.

► **homozygous**: referring to an organism that has two copies of the same allele for a given trait— $pp$  or  $PP$

► **heterozygous**: referring to an organism that has a dominant allele and a recessive allele for a given trait— $Pp$

### USING PUNNETT SQUARES TO PREDICT THE OUTCOMES OF GENETIC CROSSES

Heterozygous Parents	Homozygous Dominant Parents	Homozygous Recessive Parents
Two pea plants, each with one dominant allele, $P$ , and one recessive allele, $p$ , are crossed.	Two pea plants, each with two copies of the same dominant allele, $P$ , are crossed.	Two pea plants, each with two copies of the same recessive allele, $p$ , are crossed.
		
Possible outcomes of first generation offspring: <ul style="list-style-type: none"> <li>• 1/2 of the offspring are <b>heterozygous</b></li> <li>• 1/4 of the offspring are <b>homozygous</b> for the dominant allele <math>P</math></li> <li>• 1/4 of the offspring are <b>homozygous</b> for the recessive allele <math>p</math></li> </ul>	Possible outcomes of first generation offspring: <ul style="list-style-type: none"> <li>• all the offspring are <b>homozygous</b> for the dominant allele <math>P</math></li> <li>• all the offspring are true breeding for purple flowers</li> </ul>	Possible outcomes of first generation offspring: <ul style="list-style-type: none"> <li>• all the offspring are <b>homozygous</b> for the recessive allele <math>p</math></li> <li>• all the offspring are true breeding for white flowers</li> </ul>

The left column summarizes the work in Example Problems 2.1 and 2.2. Each time Mendel set up a heterozygous cross, he noted that close to 1/4 of the offspring demonstrated the recessive trait and about 3/4 of the offspring demonstrated the dominant trait. Remember, the fractions that result from Punnett squares only indicate the probability of that characteristic appearing with each cross.

### Practice

In people, the ability to roll a tongue is dominant over non-tongue rolling. As you solve the following problems, use  $R$  to represent the dominant allele for tongue rolling and  $r$  to represent the recessive allele for non-tongue rolling.

16. Use letters to describe the genotype of each following individual.

- a homozygous tongue roller
- a heterozygous tongue roller
- a homozygous non-tongue roller

17. a. Draw a Punnett square for the cross of a homozygous tongue roller with a homozygous non-tongue roller.

- State the likely percentage probability that the offspring will be able to roll their tongues.
- State the likely percentage probability that the offspring will not be able to roll their tongues.
- State the likely percentage probability that the offspring will be able to roll their tongues but will also carry the recessive non-tongue rolling gene.

## Genotype Versus Phenotype

Since dominant traits are expressed and recessive traits are masked, if a dominant allele is present it is easy to determine whether someone possesses at least one dominant allele. If you can roll your tongue, it means that you have a dominant allele for tongue rolling. The physical expression of the alleles that you possess is called the **phenotype**. The phenotype for the tongue-rolling trait would either be *tongue roller* or *non-tongue roller*. An organism's genotype is a description of the alleles that it possesses. The genotype for tongue rolling could be homozygous dominant ( $RR$ ) heterozygous ( $Rr$ ) or homozygous recessive ( $rr$ ). It should be noted that a person with the genotype  $RR$  and the genotype  $Rr$  both have the same phenotype since they can both roll their tongues, even though their genotypes are different.

**phenotype:** the physical and physiological traits of an organism

### Practice

Use the following information to answer questions 18 to 20.

Nectarines and peaches are genetic variations of the same fruit. The fuzzy skin of a peach is produced by a dominant allele,  $N$ , and the smooth skin of a nectarine is produced by a recessive allele,  $n$ .



18. State whether the skin phenotype of the following individuals is fuzzy or smooth.
  - a.  $NN$
  - b.  $Nn$
  - c.  $nn$
19. State the likely genotype of each example.
  - a. a smooth-skinned nectarine
  - b. a fuzzy-skinned peach bred from a cross between a peach-producing tree and a nectarine-producing tree
  - c. a fuzzy-skinned peach produced from a long line of peach-producing trees

20.
  - a. Draw a Punnett square for a cross between a heterozygous peach and a homozygous nectarine.
  - b. Use your answer from question 20.a. to determine the probability of this cross producing the genotypes  $NN$ ,  $Nn$ , and  $nn$ .
  - c. Use your answer from question 20.a. to determine from this cross the probability of offspring produced with the smooth-skinned nectarine phenotype and the probability of offspring produced with the fuzzy-skinned peach phenotype.
  - d. Determine what percentage of the offspring will carry the allele for smooth skin.
  - e. Is it possible for a nectarine to be heterozygous for the skin-type trait? Explain.
21. The ability to taste the chemical phenylthiocarbamide (PTC) is dominant over the inability to taste the chemical. Observe the following Punnett square from a cross between a male PTC taster and a female PTC non-taster ( $Tt \times tt$ ).

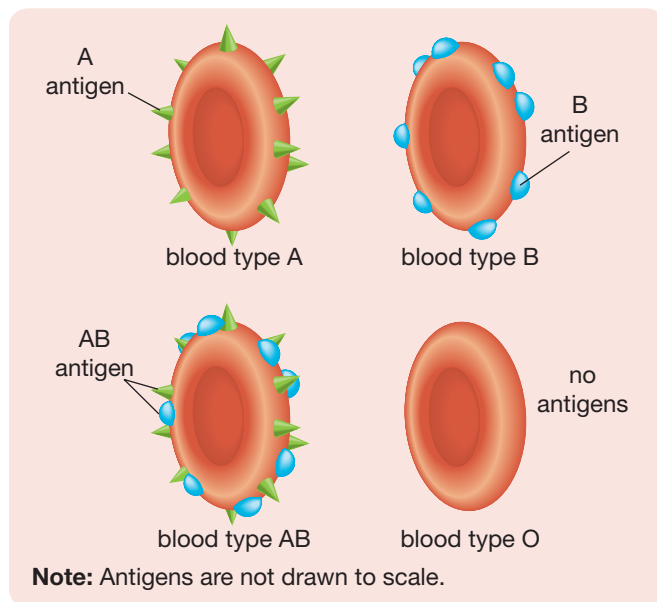
	$t$	$t$
$T$	$Tt$	$Tt$
$t$	$Tt$	$Tt$

- a. Describe the PTC tasting genotype of the offspring.
  - b. Describe the PTC tasting phenotype of the offspring.
22. In people, curly hair is dominant over straight hair. A homozygous, curly haired man ( $CC$ ) is about to have a child with a homozygous, straight-haired woman ( $cc$ ).



- a. Draw the Punnett square for this cross.
- b. Determine the probability that their child will have curly hair.
- c. Re-examine the photo of the family on pages 76 and 77. Use a Punnett square to suggest an explanation for the child's straight hair.

## Other Mechanisms of Inheritance



Not all traits are controlled by one gene or have only two alleles for a gene. Hair and eye colour do not appear in only two forms because they are controlled by more than one pair of genes. Blood type is an example of a trait with more than two possible alleles. There are three forms or alleles of the blood-type gene represented by the letters *A*, *B*, and *O*. These three alleles can produce four phenotypes. The different forms of *A* and *B* produce a modified surface protein on red blood cells that give the cell its unique phenotype. In this case, the phenotype is observed in terms of the type and presence of antigens on the surface of the blood cell. The *O* allele is a recessive form of the gene that does not produce a modified surface protein and can be masked by the *A* and *B* alleles. To express the *O* blood type, an individual must be homozygous for the *O* allele. Although the *A* and *B* alleles are both dominant over the *O* allele, *A* and *B* are different modifications of the surface and do not mask one another. Since neither state *A* nor *B* is dominant over the other, they are said to exhibit codominance, which is a condition where both allele products are expressed at the same time. This results in the *AB* phenotype.



If you know your blood type, include this information in your health file.

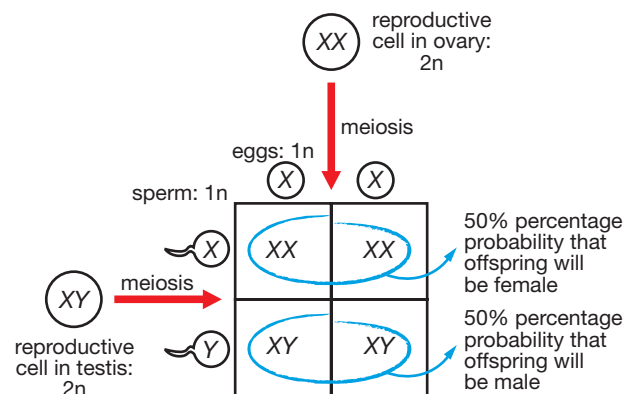
Table of Blood Types	
Genotype	Phenotype
OO	blood type O
AA or AO	blood type A
BB or BO	blood type B
AB	blood type AB

## Boy or Girl? Determining Gender

In Lesson 2.1 you looked at the different chromosomes present in a cell nucleus. If you compare the chromosome pairs of human males and females, you will find that 22 of the 23 pairs look the same. The one major difference between the chromosomes of a male and a female is that females possess two *X* chromosomes, whereas males possess one *X* chromosome and one *Y* chromosome. *X* and *Y* chromosome inheritance determines the gender of an offspring. You can use a Punnett square to illustrate how gender is determined by an offspring's inheritance of the *X* and *Y* sex chromosomes.



Since the female, or mother, only has *X* chromosomes to give, all her eggs produced during meiosis normally contain a single *X* chromosome. The male, or father, has either an *X* chromosome or a *Y* chromosome to give, so his sperm will normally have either an *X* or a *Y*. When you make a Punnett square, you can see that there is always a 50% percentage probability of the gametes uniting to become a boy and a 50% chance of the gametes combining to become a girl. These percentages are probabilities, like the 50% chance of getting heads when flipping a coin. It does not mean that children will be born boy, girl, boy, girl . . .





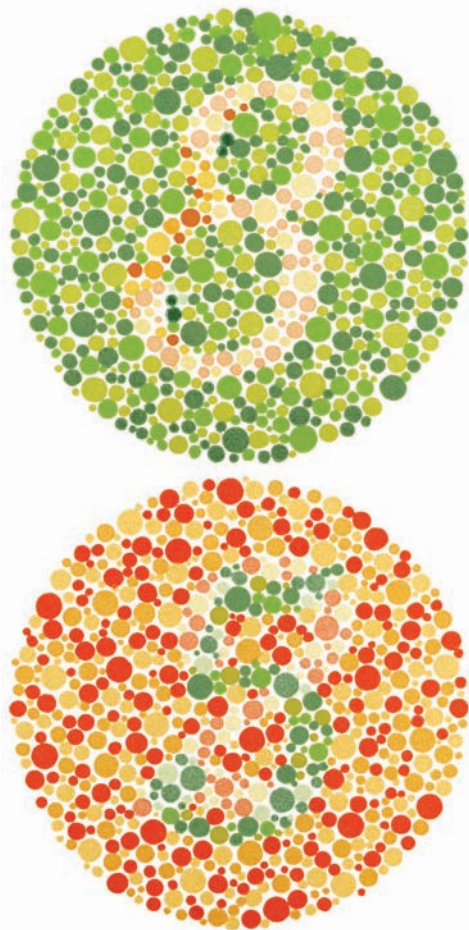
## Traits Associated with the X Chromosome

The *X* and *Y* chromosomes that determine gender also carry other genes that do not determine the sexual characteristics of the individual. Genes like these are said to be responsible for **sex-linked inheritance**. Genes carried on the other 22 pairs of chromosomes are said to be responsible for **autosomal inheritance**.

- ▶ **sex-linked inheritance:** traits not directly related to primary or secondary sexual characteristics that are coded by the genes located on the sex chromosomes
- ▶ **autosomal inheritance:** traits controlled by genes found on the 22 pairs of autosomal chromosomes

### Colour-Blindness

The term *colour-blindness* is used to refer to the inability to perceive differences between some or all colours readily recognized by people with full-colour vision. There are many types of colour-blindness. Some are caused by damage to the eyes or the optic nerves, but most are hereditary. In this chapter, colour-blindness will refer to red-green colour-blindness. People with red-green colour-blindness would be unable to identify the 8 or 5 within the following circles. This is one of the most common types of colour-blindness, and it is caused by sex-linked inheritance.



### DID YOU KNOW?

Colour-blindness is often assumed to be a disability because persons with colour-blindness are unable to detect colours to the same degree as persons without colour-blindness. However, whether a condition is a disability, an inconvenience, or an ability depends very much upon the specific environment the person is in.



In a hunting or a military environment, people with colour-blindness have an advantage when it comes to seeing objects against confusing backgrounds. In this case, colour-blindness should be referred to as *special counter-camouflage ability*.

Clearly, the context provided by the environment plays a key role in determining whether a condition is also a disability.

A Punnett square can be used to make predictions about sex-linked traits. The traits are represented as uppercase and lowercase letters for dominant and recessive alleles, like they are with autosomal traits. The only difference between autosomal and sex-linked Punnett squares is that the letters used to represent the sex-linked traits for alleles are written as superscripts above the chromosome on which they are carried. Let  $N$  represent the allele for full-colour vision and let  $n$  represent a recessive allele that produces the condition of colour-blindness.

Because colour-blindness is an *X* chromosome, sex-linked trait, the allele is not carried on the *Y* chromosome, and the possible genotypes are  $X^N$  and  $X^n$ . A complete male genotype for a colour-blind man would be represented as  $X^nY$  and a man with full-colour vision would be represented as  $X^NY$ . A female with full-colour vision who carries the recessive allele for colour-blindness would be written as  $X^NX^n$  and a colour-blind female would be written as  $X^nX^n$ .



### Example Problem 2.3

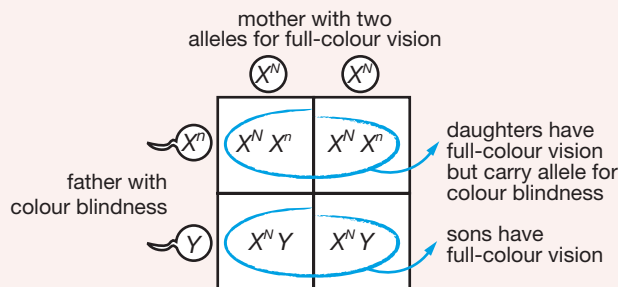
A homozygous woman who has two alleles for full-colour vision has children with a colour-blind man.

- Describe the genotype of each parent.
- Build a Punnett square to predict the possible genotypes of their children.
- Use the Punnett square to explain why the sons have full-colour vision even though their father is colour-blind.
- Use the Punnett square to explain why the daughters are carriers for the colour-blind allele, even though they have full-colour vision.

#### Solution

- The mother's genotype would be  $X^N X^N$ , and the father's genotype would be  $X^n Y$ .

b.



- The sons are male because they inherited a  $Y$  chromosome from their father and an  $X$  chromosome from their mother. Since the  $X$  chromosome is the location of the allele for colour-blindness, and since the sons inherited this allele from their homozygous dominant mother, the sons have full-colour vision.
- The daughters are female because they have inherited an  $X$  chromosome from their mother and an  $X$  chromosome from their father. Since the  $X$  chromosome is the location of the allele for colour-blindness, and since the  $X$  chromosome from their father contains this allele, each daughter is a carrier of the allele for colour-blindness. However, the daughters are not colour-blind themselves because they inherited an  $X$  chromosome for full-colour vision from their mother.

### Practice

- Draw a sex-linked Punnett square for the cross between a man with full colour vision and a woman with full-colour vision who is a female carrier of the recessive colour-blind allele.
  - Determine the percentage probability of their sons being colour-blind.
  - Determine the percentage probability that their daughters will be carriers of the recessive colour-blind allele even though the daughters have full-colour vision.
- Draw a sex-linked Punnett square for the cross between a colour-blind man and a woman with full-colour vision who is a female carrier of the recessive colour-blind allele.
  - Determine the percentage probability of their sons being colour-blind.
  - Determine the percentage probability of their daughters being colour-blind.
  - Determine the percentage probability that their daughters have full-colour vision but will be carriers of the recessive colour-blind allele.
- An expectant father who is colour-blind is afraid that his soon-to-be born son will also be colour-blind. Explain to this expectant father why it is best to look at the mother's side of the family for an indication about whether their son will become colour-blind.
- Determine which gender would be most affected if a trait were found only on a gene from the  $Y$  chromosome.

## Investigation

### Investigating Dominant and Recessive Human Traits

#### Background Information

Several human physical traits are both distinctive and easily observed. Like tongue rolling, they are caused by the presence of either dominant or recessive alleles inherited from parents.



#### Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting






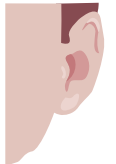




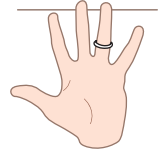
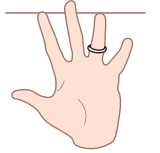
#### Purpose





You will survey the members of your class to obtain data on the presence of dominant and recessive alleles.

#### Procedure

Survey each person to discover if he or she has a dominant or recessive trait for the following eight traits. Record your findings in a table.

#### DOMINANT OR RECESSIVE TRAITS

Trait	Dominant Phenotype	Recessive Phenotype
(1) hair type	curly hair (genotype $CC$ or $Cc$ ) 	straight hair (genotype $cc$ ) 
(2) hairline	widow's peak (genotype $WW$ or $Ww$ ) 	straight hairline (genotype $ww$ ) 
(3) ear lobes	free floating (genotype $EE$ or $Ee$ ) 	attached (genotype $ee$ ) 
(4) left-handed or right-handed	right-handed (genotype $RR$ or $Rr$ ) 	left-handed (genotype $rr$ ) 
(5) thumb position with hand folding	left thumb over right thumb (genotype $TT$ or $Tt$ ) 	right thumb over left thumb (genotype $tt$ ) 
(6) finger length	ring finger longer than index finger (genotype $FF$ or $Ff$ ) 	index finger longer than ring finger (genotype $ff$ ) 

(7) thumb curvature	“hitchhiker’s thumb” (genotype $DD$ or $Dd$ ) 	straight thumb (genotype $dd$ ) 
(8) second toe	second toe longer than big toe (genotype $GG$ or $Gg$ ) 	second toe shorter than big toe (genotype $gg$ ) 

### Analysis

1. Use your recorded class data to draw a bar graph with a dominant bar and a recessive bar for each trait.
2. Observe the number of traits where the dominant phenotype is greater than the recessive phenotype. Identify a reason for the higher frequency of certain traits in the population by using a Punnett square.
3. List your own phenotype for all eight traits.
4. Explain why it is difficult to accurately list your genotype for all eight traits.
5. Describe the phenotype of the individual who has the following genotype based on the letter used for the traits in the “Dominant or Recessive Traits” table:  $CC$ ,  $Ww$ ,  $EE$ ,  $rr$ ,  $Tt$ ,  $Ff$ ,  $DD$ ,  $gg$ .
6. Perform the following crosses for the traits studied in the table by preparing a Punnett square for each noted cross. State the predicted genotype ratios and phenotype ratios of the offspring for each cross noted.
  - a. An individual homozygous for attached ear lobes has a child with a heterozygous free-floating, ear-lobed person.
  - b.  $GG \times gg$
  - c. A straight-haired individual has a child with another straight-haired individual.

## 2.2 Summary

Traits such as hair colour and eye colour passed on from your parents are called inherited traits. Traits learned or gained from the results of experiences, such as languages and injuries, are called acquired traits.

The forms of a gene are called alleles and can be either dominant or recessive. Dominant alleles are expressed or they mask the presence of recessive alleles. The effect of recessive alleles is observed only when an individual possesses two recessive copies of the allele for that particular trait.

Punnett squares are one way to predict the probability of inheriting genetic traits. Letters are used to represent genes in a Punnett square cross—upper-case letters are used to represent dominant alleles and lower-case letters are used to represent recessive alleles. When the two copies of an allele are either both dominant or both recessive, it is called a homozygous condition (e.g.,  $PP$  or  $pp$ ); and when the two genes are a different allele form, it is called heterozygous (e.g.,  $Pp$ ).

The expression of genes as observable characteristics is called a phenotype and is determined by the alleles present in an individual’s genotype.

Punnett squares can also be used to predict the gender of offspring. Some genes that do not directly relate to sexual characteristics are found on sex chromosomes. These genes are said to be sex-linked rather than autosomal. Colour-blindness is an example of a trait that affects men more often than women.



## 2.2 Questions

### Knowledge

1. Jim has dark curly hair, brown eyes, and a large scar on his cheek. As a child, he regularly practised the piano and became a gifted pianist. He is a skilled downhill skier and loves all winter sports. From this description, list Jim's genetically inherited traits and the traits that he has acquired.
2. A genotype for the fur-colour trait in mice is abbreviated as  $Mm$ .



- a. State the dominant allele in the genotype.
  - b. State the recessive allele in the genotype.
  - c. Is this individual described as homozygous or heterozygous?
  - d. If black fur is dominant over white fur in mice, state the phenotype of the mouse with the genotype  $Mm$ .
3. In cats, the gene that causes the ginger- or orange-fur colour is a sex-linked trait carried on the  $X$  chromosome. The ginger colour ( $G$ ) is dominant to the black colour ( $g$ ).
- a. Write the genotype for a ginger male cat.
  - b. Describe the phenotype of a cat with the genotype  $X^gY$ .
  - c. Describe the phenotype of a cat with the genotype  $X^GX^G$ .



### Applying Concepts

4. A family has three girls and is expecting a fourth child. What is the probability that the fourth child will be a boy?
5. Explain the difference between autosomal inheritance and sex-linked inheritance.
6. In garden peas, the yellow-seed colour is an autosomal dominant trait over the green-seed colour.



- a. Choose letters to represent the dominant and recessive alleles for this trait. Write the genotypes for a pea plant that is homozygous for yellow, homozygous for green, and heterozygous for yellow.
  - b. Draw a Punnett square for a cross between a homozygous yellow-seeded pea plant and a homozygous green-seeded pea plant. State the predicted genotypes and phenotypes of the offspring.
  - c. Draw a Punnett square for a cross between two of the offspring produced in question 6.b. State the predicted genotypes and phenotypes of the offspring.
7. The gene for eye colour in fruit flies is located on the  $X$  chromosome. The allele for the dominant red-eye colour could be represented by the allele  $X^R$ , while the allele for the recessive white-eye colour could be represented by the allele  $X^r$ .
- a. Draw a sex-linked Punnett square for a male with red eyes who breeds with a female with white eyes.
  - b. Determine the percentage probability that the male offspring will have white eyes.
  - c. Determine the percentage probability that the daughters will have white eyes.
  - d. Determine the percentage probability that the female offspring are carriers of the recessive white-eyed allele.